

Recycler 3-bump orbit analysis

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The study

- Used circulating proton beam
 - Closed orbit data with 64 turns averaging.
 - Typically 8 different bump sizes per location.
- All the way around the ring,
 - except where LEP correctors were used.
 - Data taken with skew quads at nominal setting.
- Data quality
 - Roughly 70% of data were good.
 - ✓ Anomalous orbit motion at $\sim 20 \mu\text{m}$ level.
 - ✓ Corrupted data due to time line changes.

3-bump orbit analysis

- I90
 - Polynomial fit of position data w.r.t. the first kick.
 - Output 1st, 2nd, or 3rd order coefficient to R39 BPM file.
- R49, using "Magnet Move" option
 - Read in orbit from R39 BPM file.
 - Disable all quad/gradient magnets except within the 3-bump region.
 - Send data to MICADO for fitting
 - ✓ tecker.fnal.gov
 - Look for sign of BPM coupling.
- Calculate the equivalent rolled angle for coupling
 - Interpretation of fitted kick amplitudes.
 - Sort data for plotting

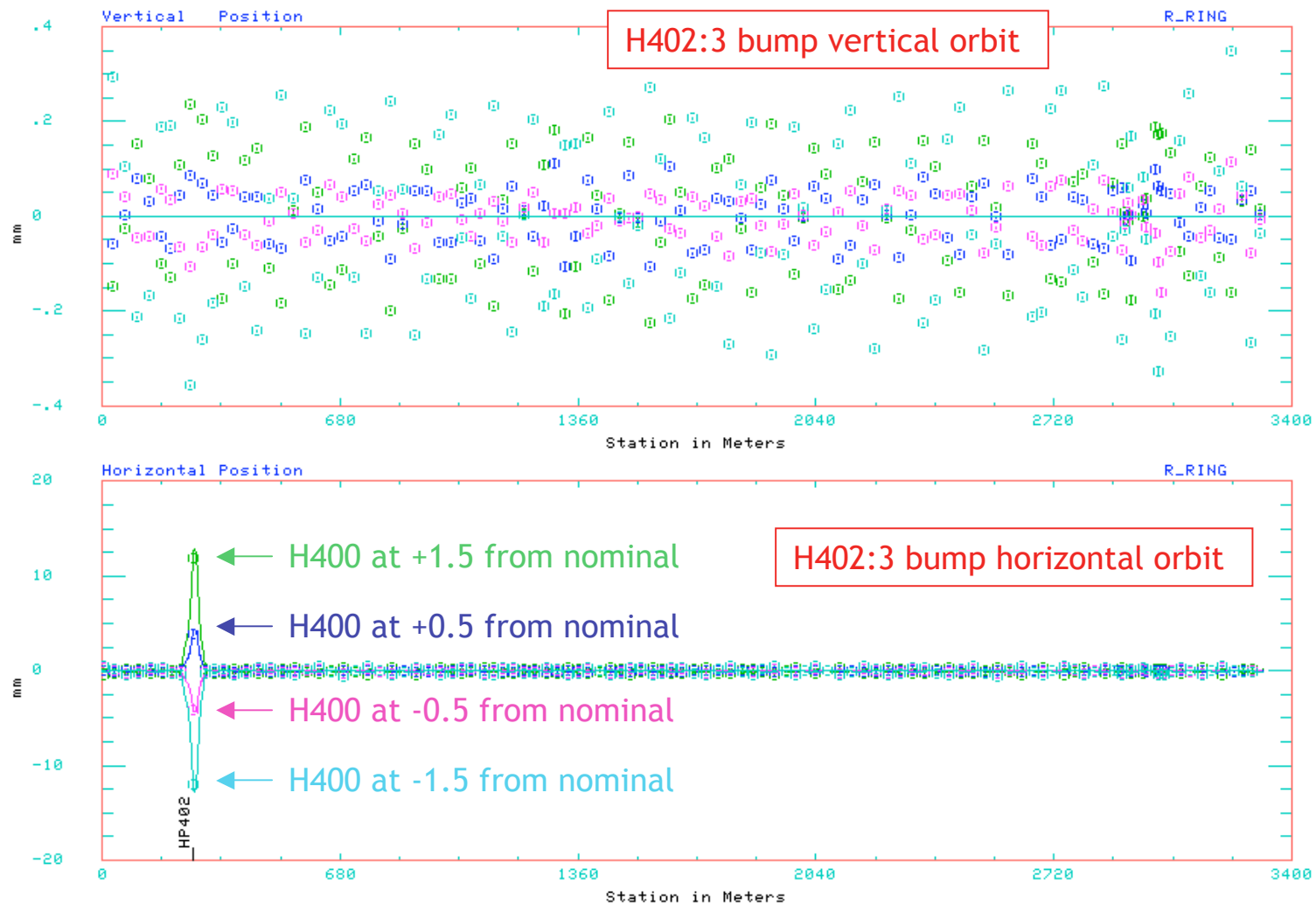
H402:3 bump analysis result

- First order
 - coupling
 - ✓ equivalent to roll Q402B by 4 degrees.
- Second order
 - Horizontal plane, (bump leakage)
 - ✓ H400 is likely the source.
 - ✓ No evidence of sextupole content.
 - Vertical plane
 - ✓ Major kick source at Q402B
 - ✓ Implies existence of skew sextupole
 - ✓ Likely from LAM402.

State of analysis

- First order orbit analysis
 - Completed 1st pass
 - ✓ Coupling locations found.
 - ✓ Rolled Trim dipoles.
 - ✓ Rolled BPMs.
- 2nd & 3rd order orbit analysis
 - skew sextupole.
 - Octupoles.
 - skew Octupoles.
- Trim calibration
 - Bump closure analysis.
- The result not exhaustive
 - Available data does not cover the entire ring.

H402 closed 3-bump orbits

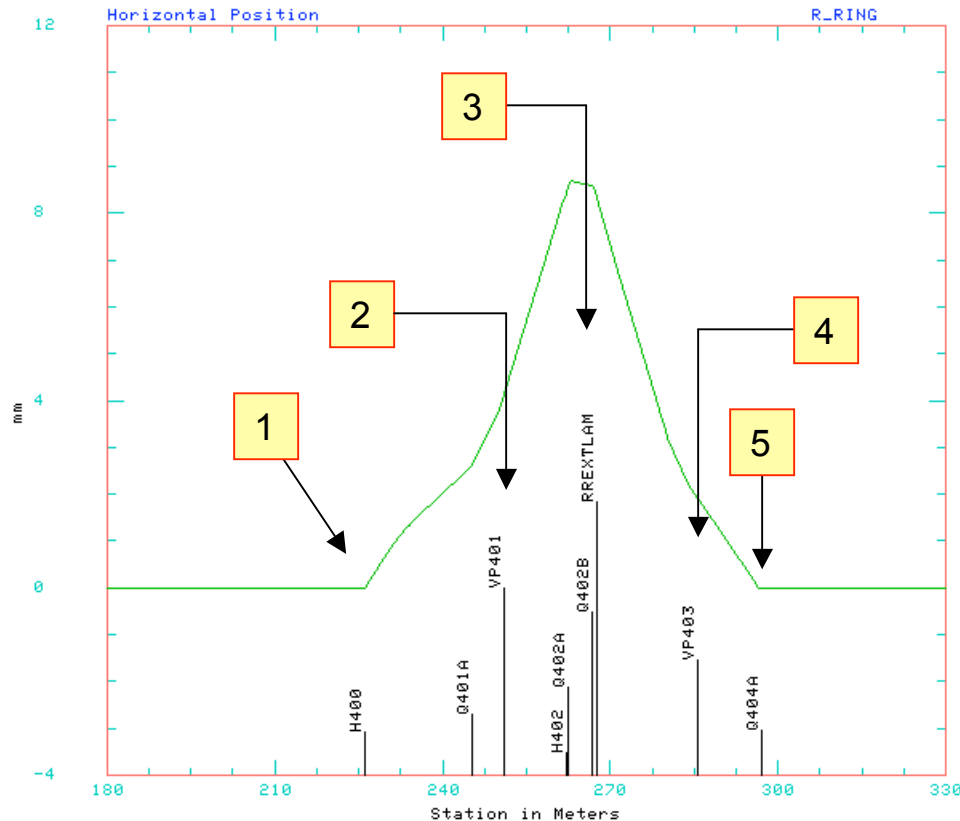


Signs of anomalous orbit kicks



What we get with closed 3-bump data

Using H402:3 bump as an example



Vertical kick sources implies:

Location 1 & 5:

- Rolled trim dipoles

Location 3:

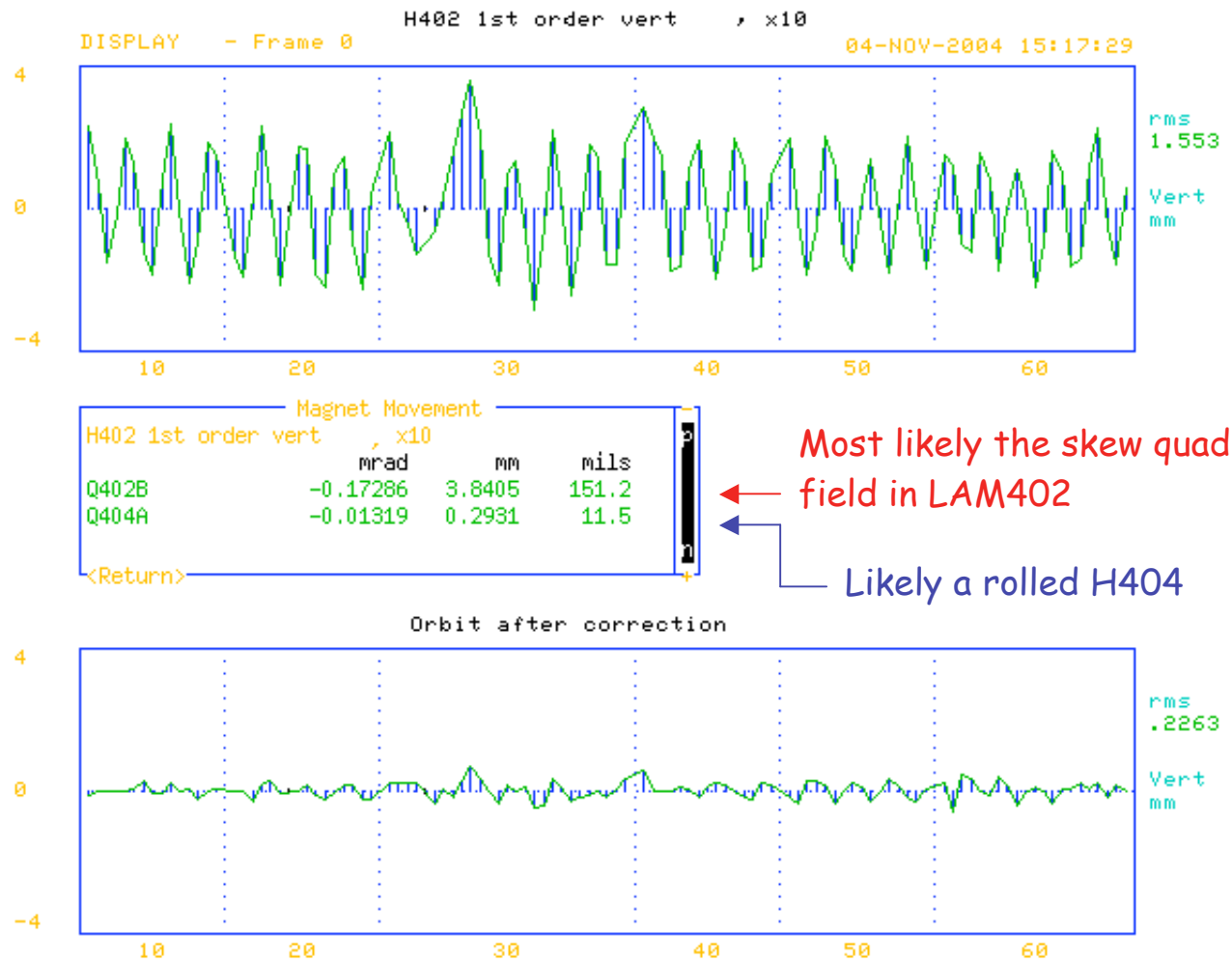
- Skew quad
- Rolled trim dipole

Excess vertical BPM position readings

Location 2 & 4

- Rolled BPMs.

H402 3-bump 1st order, vertical



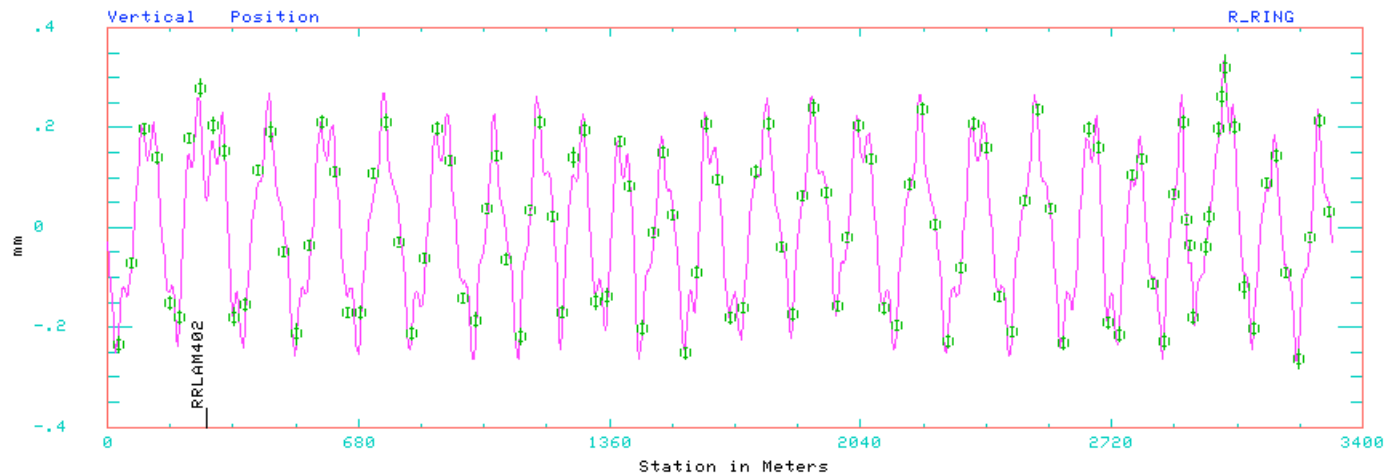
Turning R49 fit results into roll angles

	Bump plane	Horizontal	FALSE	<input type="checkbox"/> Bump vertical					
	Data plane	Vertical	TRUE	<input checked="" type="checkbox"/> Data vertical					
		H402	490				<input checked="" type="checkbox"/> In degree		
				New Inputs					
	Type	Device	Bump pos	Cross-plane	BPM data	R49 fit, mr	BPM, deg	Trim, deg	quad, deg
479	VKICKER	V341	0.00000						
480	VMONITOR	VP341	0.00000						
481	HMONITOR	HP400	0.00000						
482	HKICKER	H400	0.00000						
483	SBEND	G400A	0.38088						
484	QUADRUPOLE	Q400B	0.64309						
485	VKICKER	V401	1.56033						
486	QUADRUPOLE	Q401A	1.63668						
487	QUADRUPOLE	Q401B	2.26677						
488	VMONITOR	VP401	2.56151		0.049		1.10		
489	HMONITOR	HP402	4.99224						
490	HKICKER	H402	5.22542			-0.017286		69.99	
491	QUADRUPOLE	Q402A	5.33695						
492	QUADRUPOLE	Q402B	5.22008			-0.017286			-4.22
493	QUADRUPOLE	Q403A	1.96805						
494	QUADRUPOLE	Q403B	1.29723						
495	VKICKER	V403	1.25168						
496	VMONITOR	VP403	1.16760						
497	HMONITOR	HP404	0.10407						
498	HKICKER	H404	0.00000			-0.001319		-0.72	
499	QUADRUPOLE	Q404A	0.00000						
500	SBEND	G404B	0.00000						
501	SBEND	G405A	0.00000						
502	SBEND	G405B	0.00000						

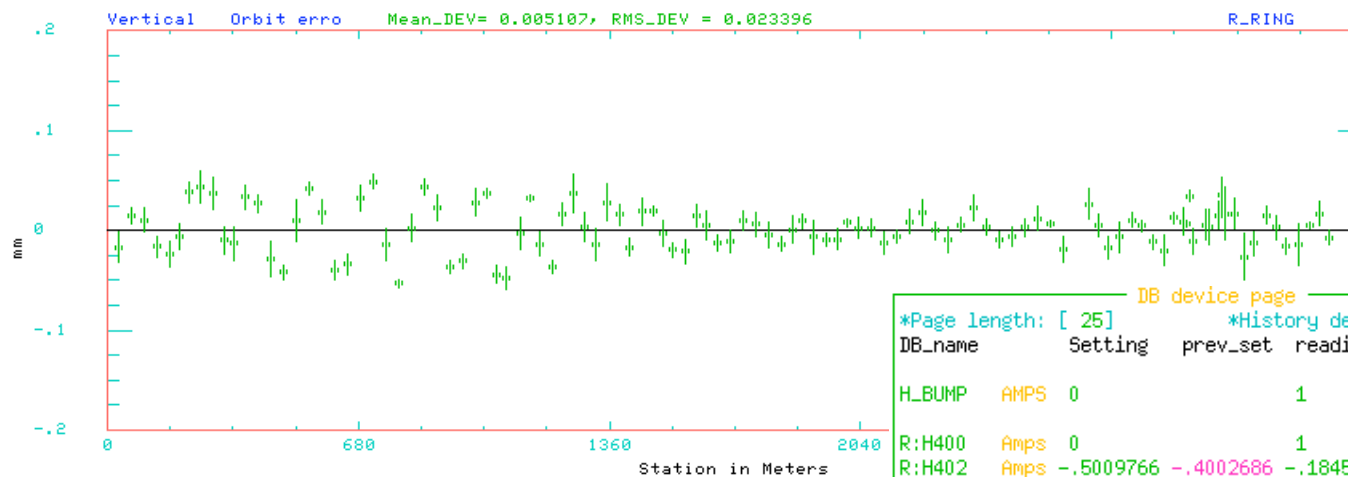
R49 fit result example

		Flag	Device name	mrاد	mm	mils	quad,deg	trim,deg	BPM,deg
H100	1ST ORDER VERT	1	Q100B	-0.0022	0.0489	1.9	0.75		
H102	1ST ORDER VERT	2	G100A	-0.00202	0.029	1.1	-4.37		
		1	or h100	-0.00202				-0.99	
H104	1ST ORDER VERT	1	Q103B	-0.0008	-0.0185	-0.7	0.43		
h400	1st order vert		vp341		0.0621				1.48
h402	1st order vert	4	Q402B	-0.01109	0.2463	9.7	-2.7		
			vp401		0.049				1.1
			or						
	(mly)	1	Q402B	-0.017286	0.38405	15.12	-4.22		
		1	h404	-0.001319				-0.72	

Simulation of skew quad field in LAM402



H402:3 bump:
1st order
vertical orbit,
data & simulation

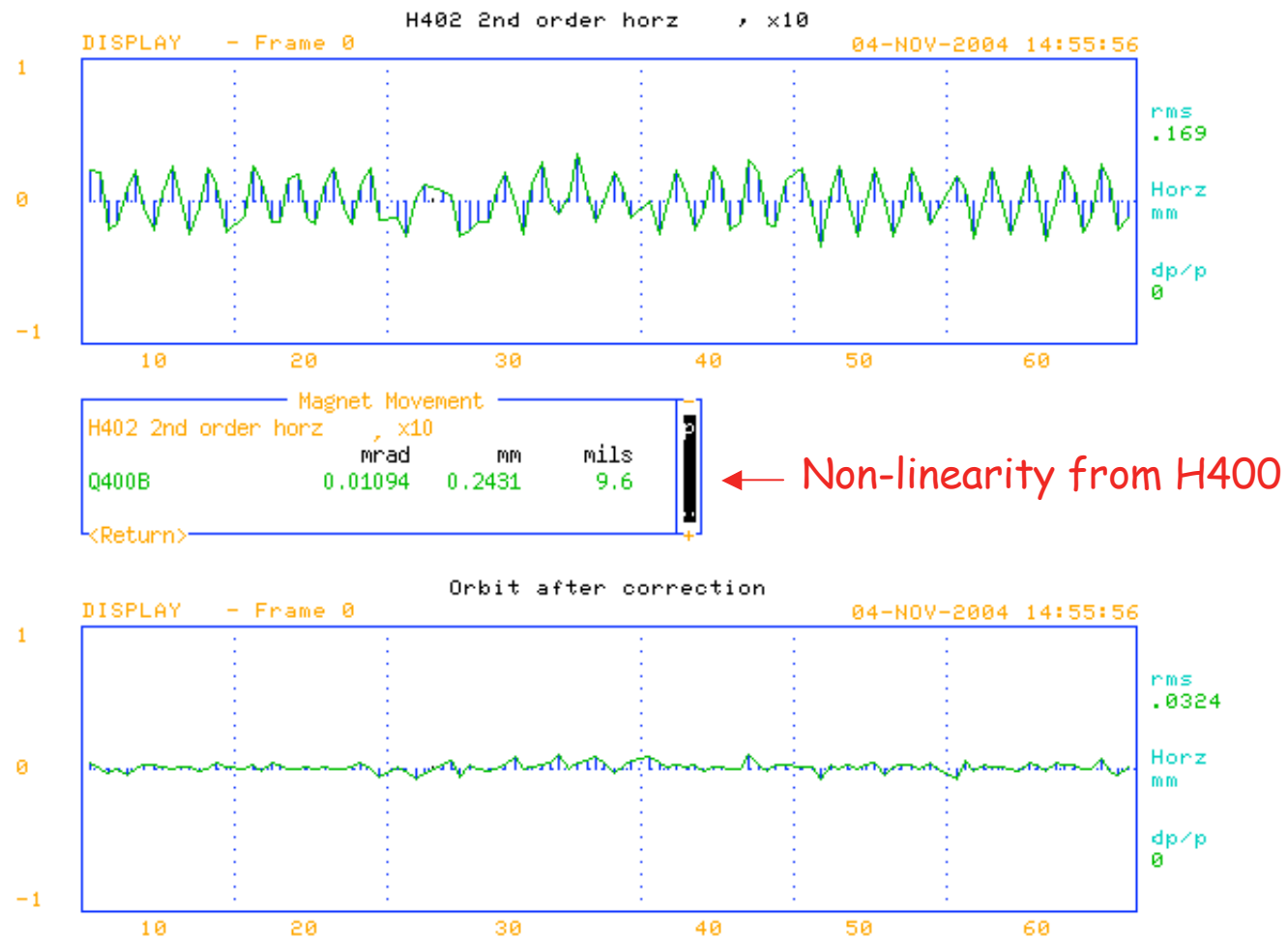


Differences,
data & simulation

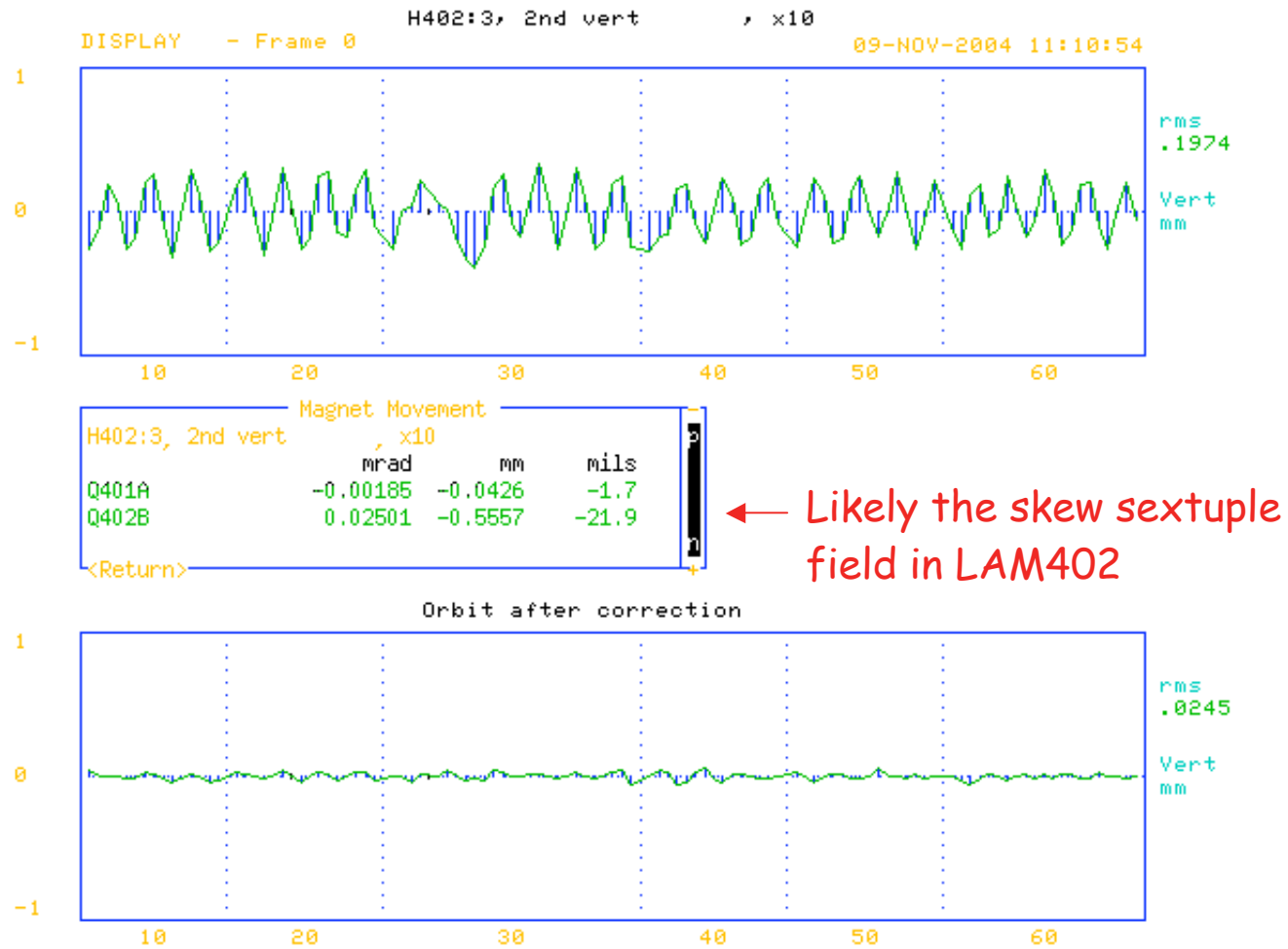
Skew quad strength used in simulation →

DB device page				
*Page length: [25]		*History depth:[15]		
DB_name	Setting	prev_set	reading	prev_read
H_BUMP	AMPS 0		1	0
R:H400	Amps 0		1	0
R:H402	Amps -.5009766	-.4002686	-.1845946	0
R:H404	Amps 1.397827	.6489258	1.474442	0
K1LAM402	KG/M 0		.16	0
K2LAM402	KGM2 0		0	
<Exit>				

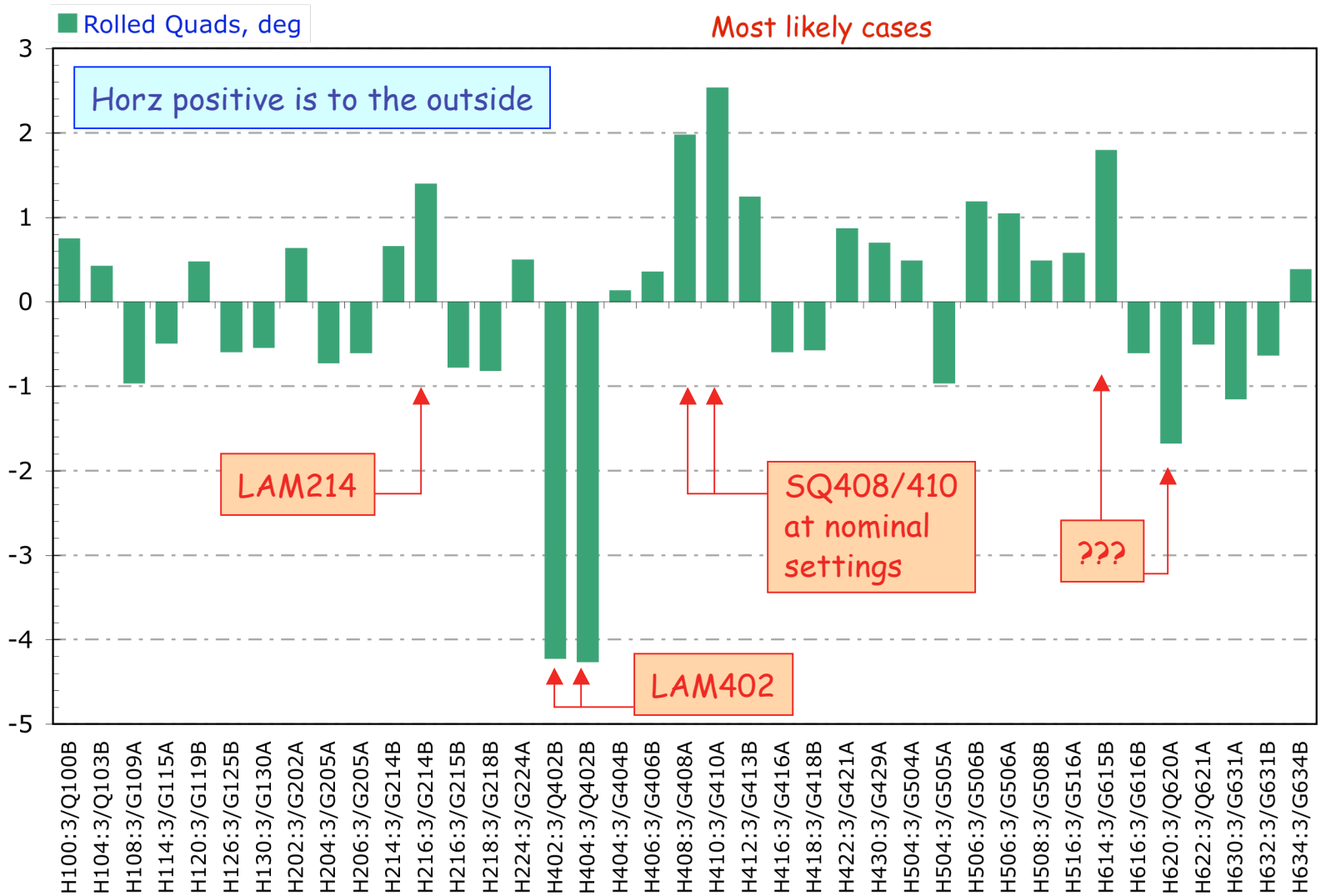
H402:3 bump, 2nd order horizontal



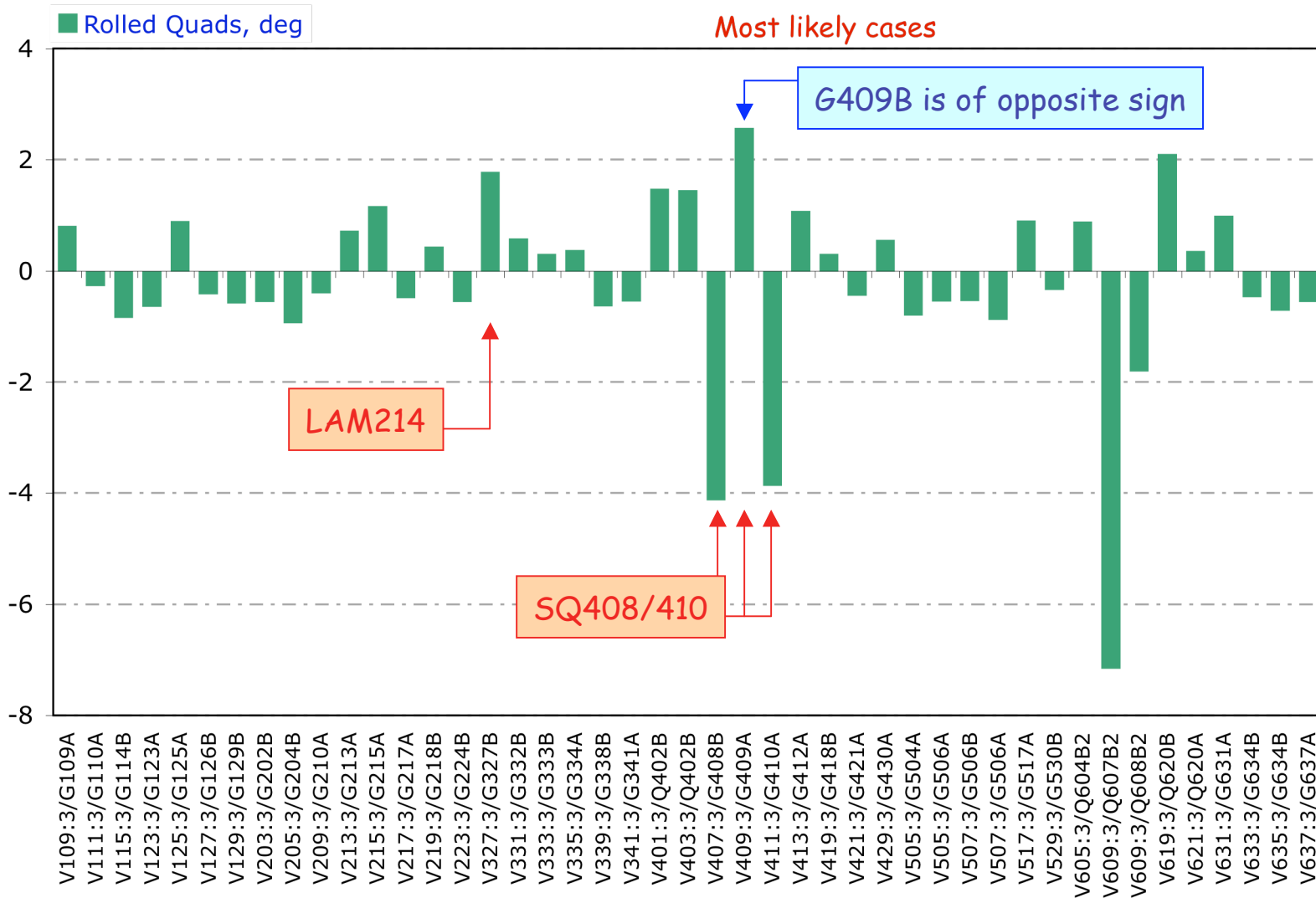
H402:3 bump, 2nd order vertical



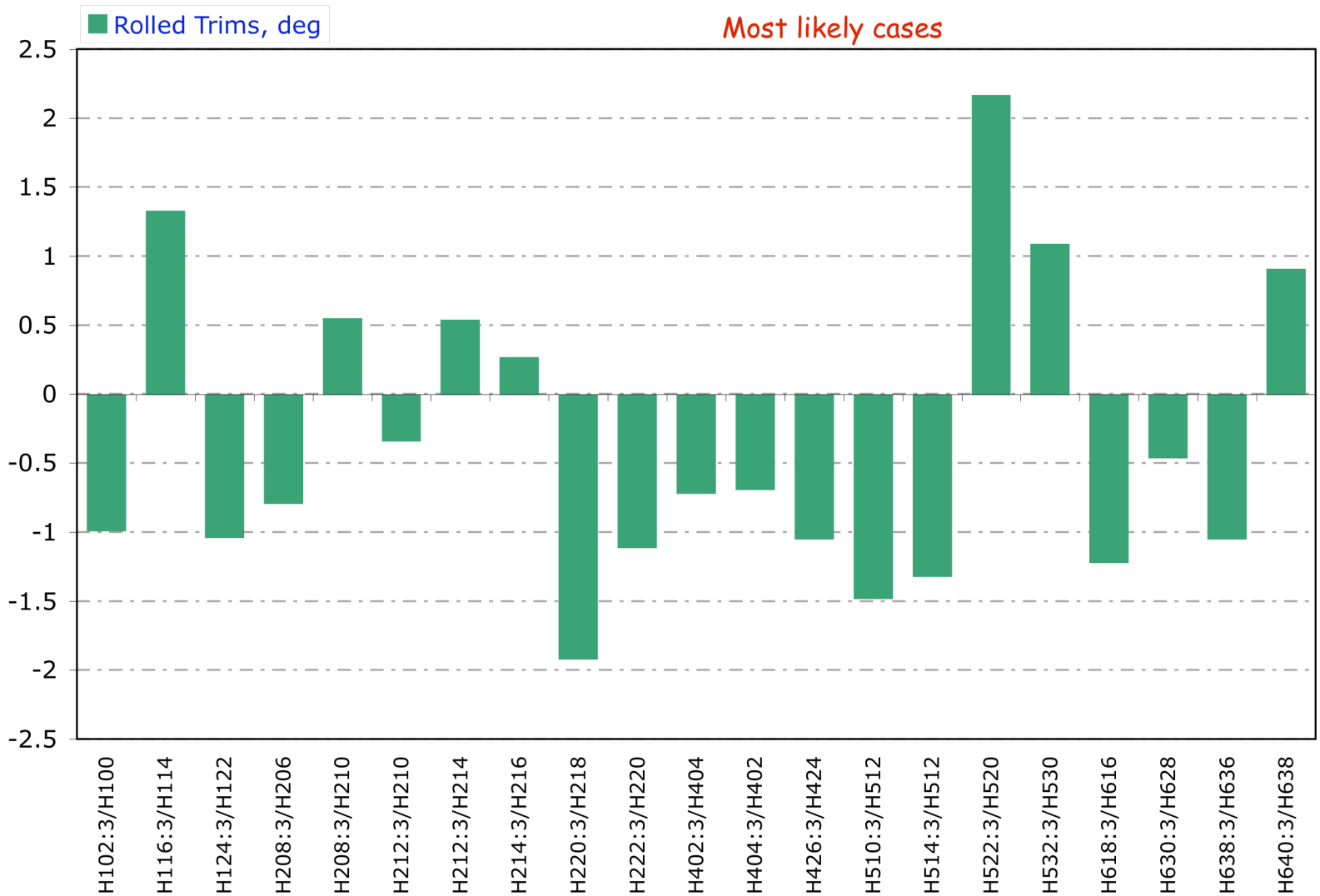
Rolled quads, Horizontal 3-bump data



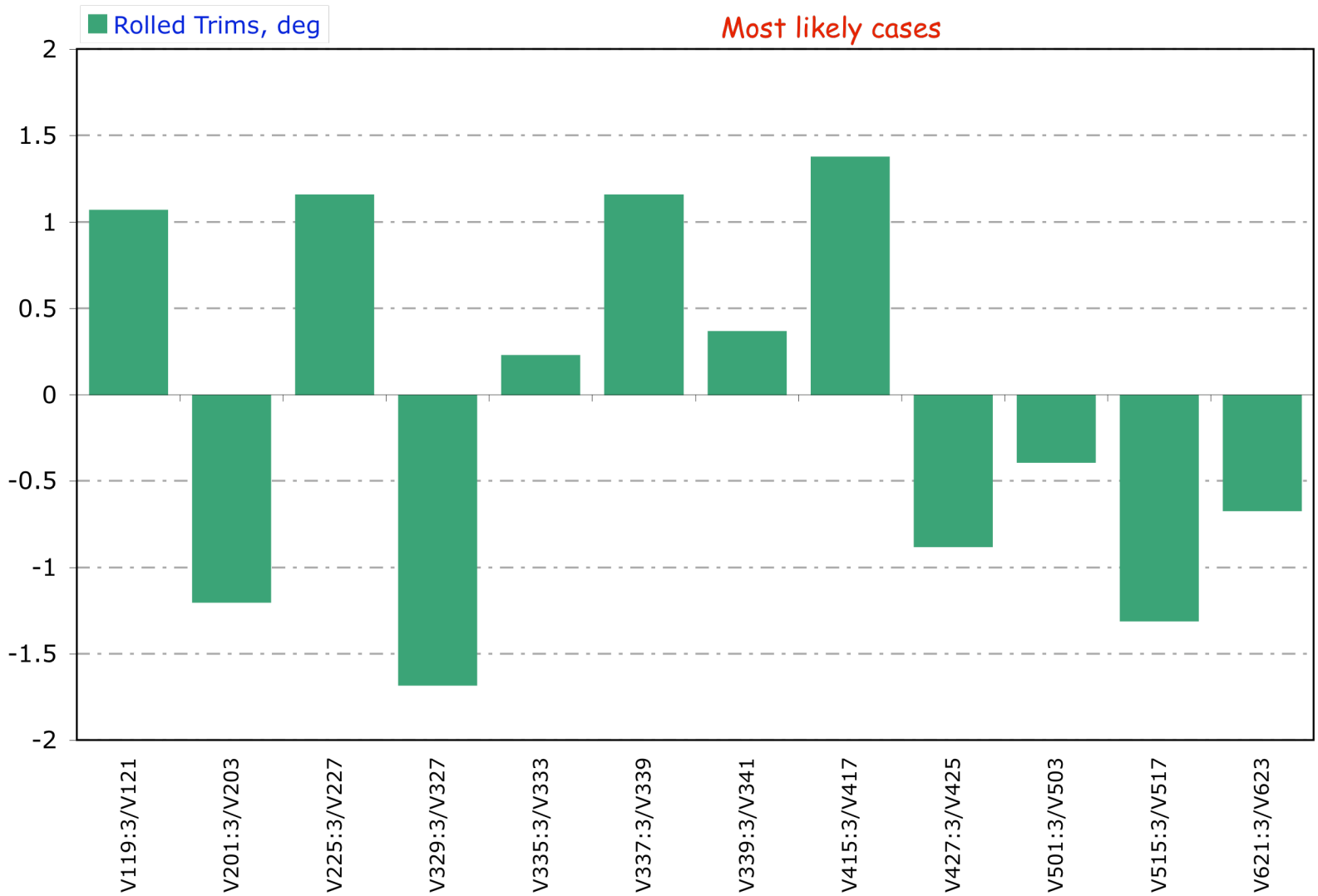
Rolled quads, Vertical 3-bump data



Rolled horizontal trims

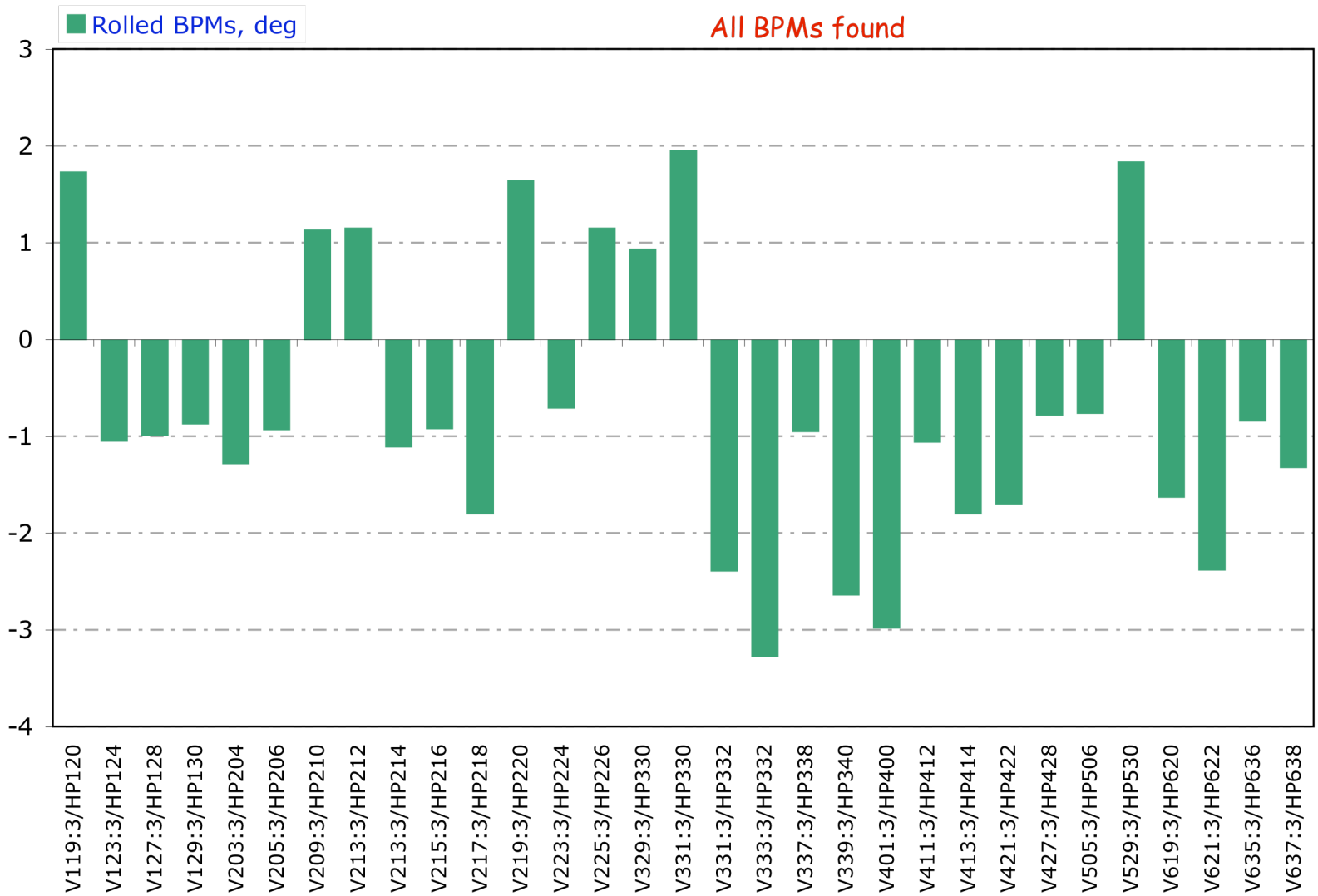


Rolled vertical trims



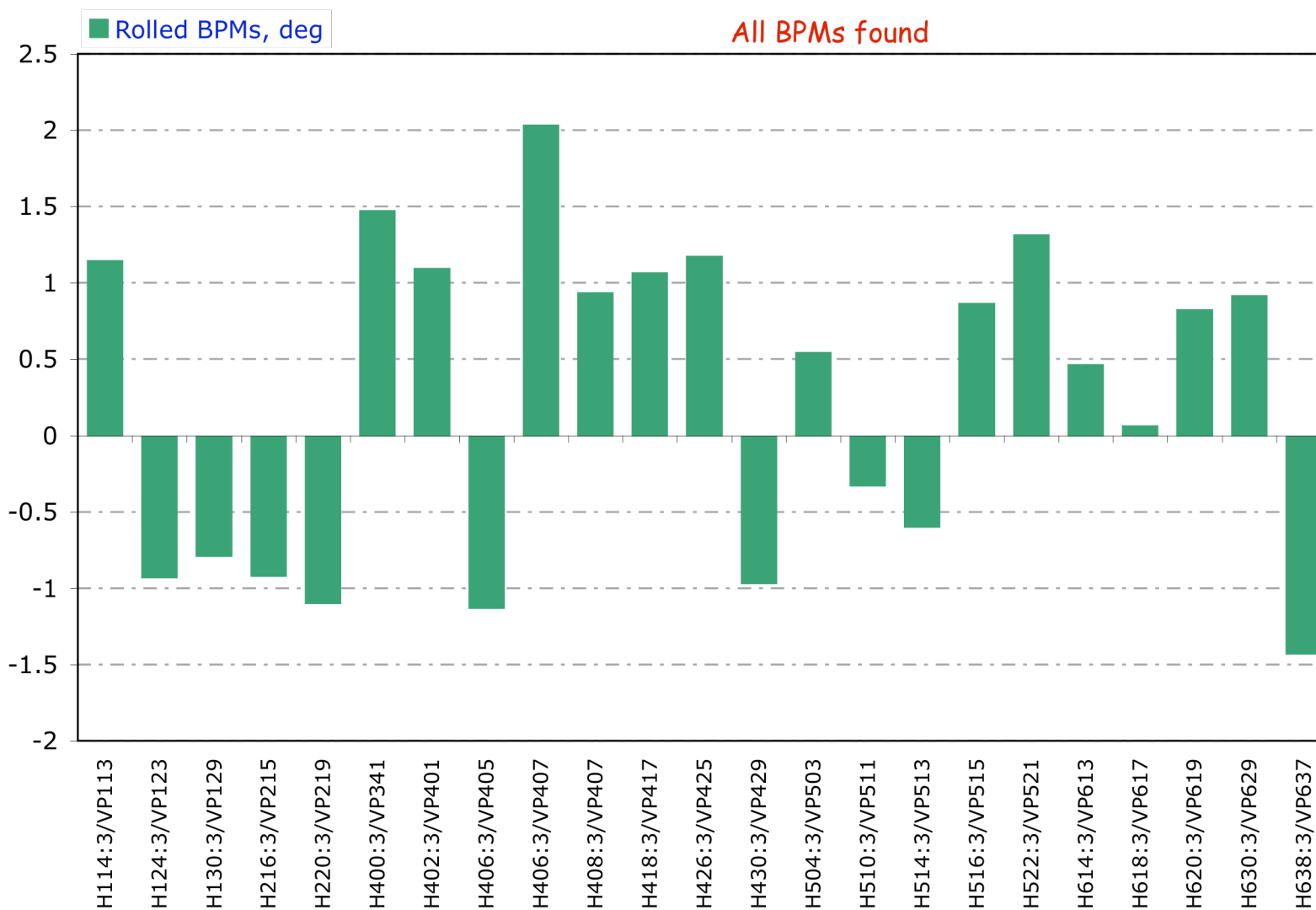
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Rolled horizontal BPMs



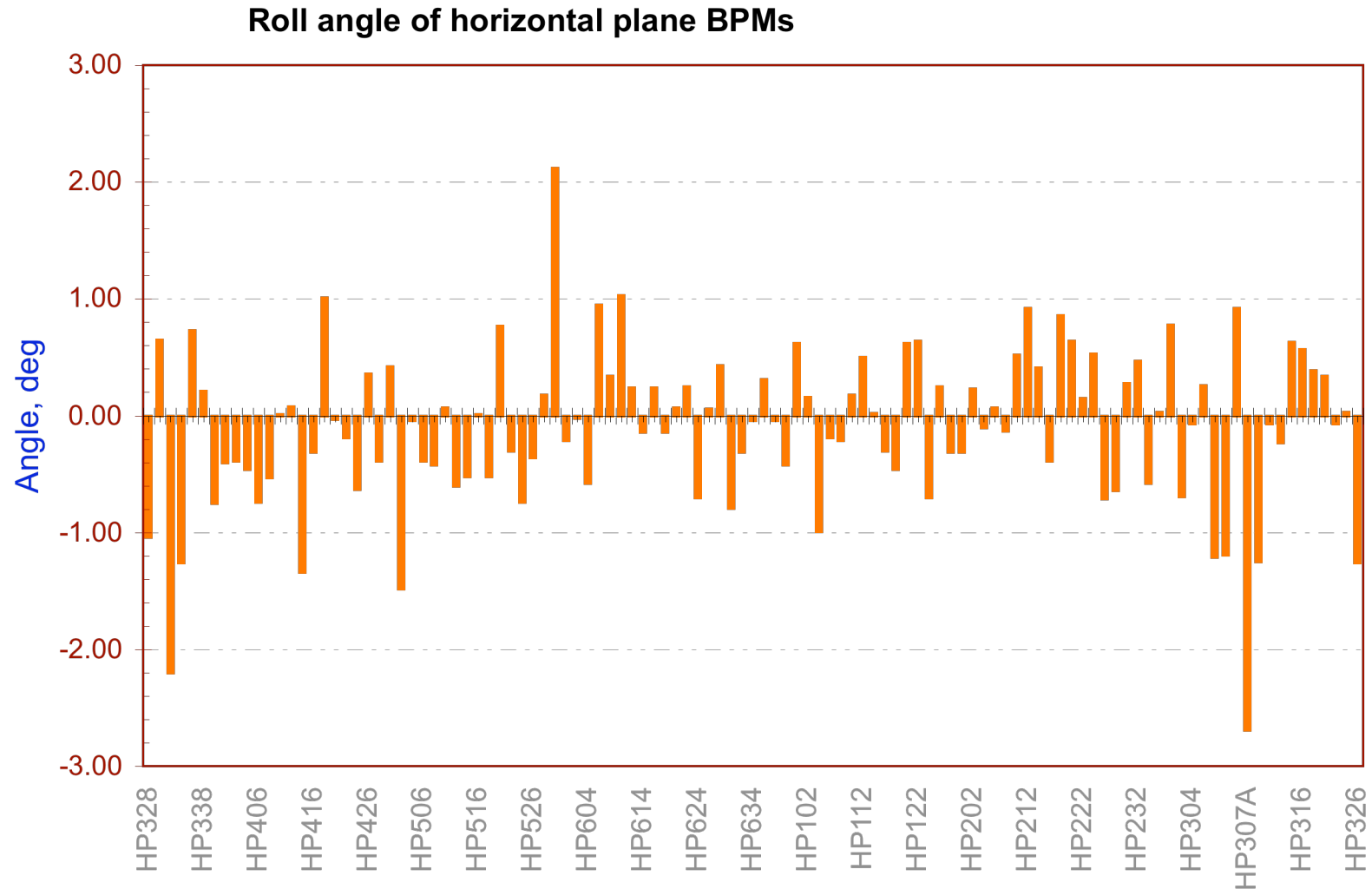
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Rolled vertical BPMs

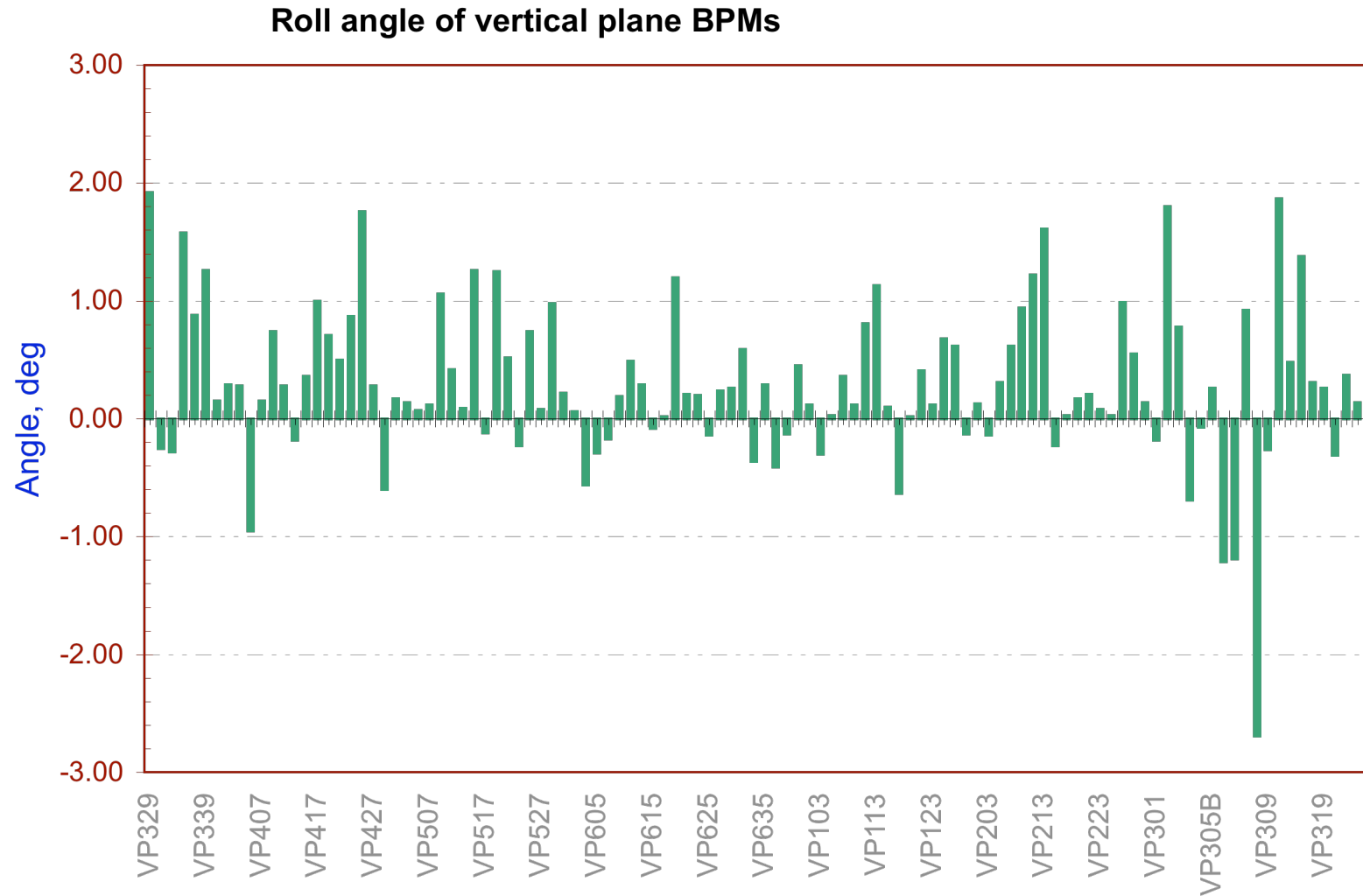


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Measured roll of horizontal BPMs, by Cons



Measured roll of vertical BPMs, by Cons



V609:3 closure example

```
DB device page
*Page length: [ 25]      *History depth:[15]
DB_name      Setting    prev_set  reading  prev_read
R_S328PM KGMM    209.184      209.184
R_S329PM KGMM   -312.486     -312.486
R_S213PM KGMM   -311.507     -311.507

R:V605  Amps  0          0
R:V607  Amps  0        -.9202881
R:V609  Amps -1.930298   -1.864746
R:V611  Amps -4.691528   -5.136621 -4.536621
R:V613  Amps  0          0

<Exit>
```

We have the 3-bump data
for most of the locations for
closure analysis.

